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Taxation and Technology Adoption: A Hotelling Approach

Ben Kriechel and Thomas Ziesemer[1]

Abstract

Environmental regulation and competitiveness are issues that seem to be at odds. However, the `Porter Hypothesis' states that firms can actually gain in competitiveness if they are subject to stricter environmental regulation. We show in a simple model the basic setting of the problem to apply it then to a Hotelling framework. A non-adoption tax (adoption subsidy) is shown to destroy a non-adoption equilibrium in a closed economy model. We show that taxes not directly targeting the non-adoption problem may fail to have an adoption incentive on the firms. In an open economy model the Porter Hypothesis is shown to hold if (i) non-adoption taxes are higher than adoption costs for one country and lower for the other, and (ii) the returns of second adoption are insufficient to cover the net adoption costs.

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The environmental Porter Hypothesis suggests (see Porter and van der Linde, 1995) that the costs of compliance with environmental standards may be partially or even fully offset by innovations they trigger and this may even lead to absolute advantages over foreign competitors. While the general fear of trade economist was rather one of ecological dumping rather than increased environmental regulation to improve competitiveness, the article was greeted with skepticism. Nevertheless, it led economists to think seriously about the gist of the Porter Hypothesis: Is it possible that firms could gain advantage over their foreign rivals through tougher environmental regulation? While classical trade theory offers no reason to believe in the Porter Hypothesis, imperfect competition models were considered promising to find some theoretical foundations to the case study and anecdotal evidence offered by Porter and van der Linde.

Empirical support for the Hypothesis is based on case study evidence (see Ayres (1994) Porter and van der Linde (1995a)). Palmer, Oates and Portney (1995) provide empirical arguments explaining why full offsets are rather unlikely. They base their argument on information provided by entrepreneurs. A problem with both of these types of information provision is that the costs of innovation precede the returns and the returns are often stretched out over decades. Jaffe and Palmer (1997) critically evaluate the Porter Hypothesis, they attempt to empirically 'test' the Hypothesis, but find no evidence supporting it. This empirical evaluation is based on the link between the stringency of environmental regulation and R&D, but not on adoption.

There have been several attempts to construct trade models based on the gist of the Porter Hypothesis. Ulph (1996a) constructs a Brander-Spencer type of strategic trade model with Cournot competition. Firms can invest in technology affecting variable costs but not the accompanying pollution. He shows that the strategic interaction between producers reduces the government's incentive to loosen environmental regulation. He concludes, though, that the reduction of pollution with the lowering of the variable costs could change that result. This is the avenue that Simpson and Bradford III (1996) pick up. They model the firms in a similar fashion, with the exception that R&D not only lowers marginal costs, but also the emission of the pollutant. The government uses effluent taxation to maximize the domestics firm's profits net of the environmental externalities of production. The government is able to force the firm into a Stackelberg-leader position relative to its foreign competitor. For some special cases of specifications and numerical parameter values they are able to construct a strengthening of regulation resulting in a shift of profits from foreign to domestic firms. However, they stress that this is not a general result and it is unlikely, that environmental regulation should be used as a policy device to induce industrial advantage.

Greaker (2003) models the Porter Hypothesis by assuming that due to the abatement technology the environment is an 'inferior input' in the production process. For some ranges of environmental taxation, this is shown to increase competitiveness. However, the impact on profits remains ambiguous.

Feess and Taistra (2001) model a two-period game with Cournot competition. The environmentally friendly technology is assumed to lead to a decrease of unit costs in the second period, however not in a way that reduces overall costs. Policy agencies of the foreign nation are assumed to stochastically imitate the national environmental regulation. As the overall costs are always higher with environmental friendly production, the strong form of the Porter Hypothesis is not reached.

Bertrand-type imperfect competition models were introduced in the context of strategic environmental trade policy in the paper by Barrett (1994). In the context of cost saving research Ulph (1996b) shows both for environmental taxation and for environmental standards that firms can benefit from tighter regulation if only the governments act strategically, but firms do not.

Principal-agent models of the Porter Hypothesis are set in the context of organizational inefficiencies. In this model type incentives between principal and agent over the choice of projects are miss-aligned. Environmental regulation helps to re-align the preferences of principal and agent, hence increases the efficiency of the firm (see for example Schmutzler (2001) and Klein and Rothfels (1999)). Ambec and Barla (2002) show that, by reducing agency costs, an environmental regulation may enhance pollution-reducing innovation while at the same time increasing firms' private benefit.

Other specifications are e.g. Mohr (2002): he uses a general equilibrium framework with a large number of agents, external economies of scale in production, and discrete changes in technology. As new technologies are modelled with an industry learning curve, firms are stuck in a non-innovating equilibrium, initially. Environmental regulation enforces the adoption of 'new technology', hence allowing for subsequent learning. However, learning is enforced by assumption rather than induced by economic incentives.

Related is Hübner (2001). Using a duopoly model of a patent race, she shows that stricter environmental policy might increase the probability of a sleeping patent instead of encouraging environmental technological progress, but the reversed case is also possible: environmental policy may activate otherwise sleeping patents.

Our model differs in that it does not postulate any preference for the consumer of green goods over non-green goods. Rather we focus on the aspect of (clean) technology adoption, environmental regulation and taxation.

We will commence by using a pedagogic 'basic model' which emphasizes a crucial point we want to make: environmental policy may destroy or shorten an non-adoption equilibrium. It explains why it may be rational not to adopt, although no opportunities are overlooked. In the second section we give a profit-maximizing version of the Porter problem using a Hotelling framework. The third section concludes.

1 Basic Idea: Environmental Policy Destroying Non-Adoption Equilibria

In this first part of the section we will only consider a duopoly case on a national market. Thus we assume away the effect of international competition and competitiveness to get expositional clarity. In a further step we will then consider effects of an international duopoly when firms face *different* national environmental regulation.

As in Tirole (1988, Chapter 10) we consider a process innovation that can be adopted at some cost, C, which is constant over time. It is assumed that $1 < C < (1+r)/r$, where r is the per-period rate of interest. If none of two firms adopts, the flow rent for both is $\Pi > 1$. If only one firm adopts it gets $\Pi + 1$ and the other gets $\Pi - 1$. Thus, the innovation merely transfers profits. If both firms adopt they both receive Π again. The additional flow profit of adoption when the other firm has already adopted is $1 > rC/(1+r)$. The interest on the adoption cost or net present value of the rent of adoption is $(1+r)/r > C$. Therefore an adopting firm whose action can be observed immediately will be followed by the other firm. This makes adoption for the first firm, anticipating the second adoption, unprofitable. Because of the perfect observation and reaction possibilities each firm can afford to wait and resist the temptation of adoption profit, $\Pi + 1$, which will vanish immediately after the competitors adoption anyway. In a pay-off bi-matrix the net present values of profits from adopting new or sticking to old

Table 1: Payoff with old and new technology

Firm 1 ↓ \ Firm 2 →	New	Old
New	$\frac{(1+r)\Pi}{r} - C, \frac{(1+r)\Pi}{r} - C$	$\frac{(1+r)(\Pi+1)}{r} - C, \frac{(1+r)(\Pi-1)}{r}$
Old	$\frac{(1+r)(\Pi-1)}{r}, \frac{(1+r)(\Pi+1)}{r} - C$	$\frac{(1+r)\Pi}{r}, \frac{(1+r)\Pi}{r}$

Table 2: Payoff with environmental taxes

Firm 1 ↓ \ Firm 2 →	New	Old
New	$\frac{(1+r)\Pi}{r} - C, \frac{(1+r)\Pi}{r} - C$	$\frac{(1+r)(\Pi+1)}{r} - C, \frac{(1+r)(\Pi-1)}{r} - T$
Old	$\frac{(1+r)(\Pi-1)}{r} - T, \frac{(1+r)(\Pi+1)}{r} - C$	$\frac{(1+r)\Pi}{r} - T, \frac{(1+r)\Pi}{r} - T$

technologies are summarized in Table 1.

Adoption of both is also an equilibrium but one with worse results than no adoption because adoption is costly. As both firms have the old technology in the beginning and both can anticipate that adoption would be followed immediately by adoption of the competitor, first adoption is self-damaging. No adoption for both is therefore the superior equilibrium for the two firms (See Tirole 1988 and Fudenberg and Tirole 1987).

Given that the new technology is not only more cost efficient, but also cleaner by assumption, the equilibrium is inferior from the consumers' point of view. "New/New" will only be an equilibrium if firms cannot observe competitors action and therefore prefer to preempt. This case of imperfect information will, however, not be considered here.

Next, suppose we have homogenous goods independent of the production technology. However, the new technology produces the good without pollution while the old one is dirty. The government punishes non-adoption with an environmental tax, T. Profits and costs are unchanged otherwise. Then, the pay-off bi-matrix changes into the one given in Table 2.

Clearly, if the environmental tax is high enough, it does not pay anymore for the two firms to stay in the non-adoption equilibrium. Formally, if $T > C$, adoption becomes

Table 3: International case with unilateral taxes

Firm 1 ↓ \ Firm 2 →	New	Old
New	$\frac{(1+r)\Pi}{r} - C, \frac{(1+r)\Pi}{r} - C$	$\frac{(1+r)(\Pi+1)}{r} - C, \frac{(1+r)(\Pi-1)}{r}$
Old	$\frac{(1+r)(\Pi-1)}{r} - T, \frac{(1+r)(\Pi+1)}{r} - C$	$\frac{(1+r)\Pi}{r} - T, \frac{(1+r)\Pi}{r}$

profitable even disregarding the action of the other duopolist. Both adopt the new, clean technology. Without the tax, the technology would never have been adopted (see Table 1).

Proposition 1.1 *Sufficiently high environmental taxes can force firms out of a non-adoption equilibrium.*

However, this argumentation so far falls short of the Porter Hypothesis in the original, strong sense which (also) implies a competitive advantage for the nation that introduces the environmental regulation. Let us assume free trade, so there is no tariff protection, and that the home country, believing in the Porter Hypothesis introduces the environmental tax or regulation at cost T. Firm 1 is located in 'Home', while firm 2 is located in 'Foreign', competing on a third market without transport costs or tariffs. Foreign does not introduce any regulation, hence the pay-out matrix looks like Table 3.

We will now derive the conditions the tax has to fulfill, in order to be effective, and also examine the effect of the tax in terms of the Porter Hypothesis. Firm 1 will adopt the new technology if the net pay-off from adopting is higher than from non-adopting. Let us examine separately the cases for a foreign firm 2 following adoption, and for a foreign firm 2 that will not adopt. Let us assume for the moment that foreign firm 2 will not adopt at all, then the best strategy for firm 1 is to adopt if:

$$\frac{(1+r)(\Pi+1)}{r} - C > \frac{(1+r)\Pi}{r} - T$$

Subtracting $\frac{\Pi(1+r)}{r}$ on both sides yields

$$\frac{(1+r)}{r} > C - T$$

and after division by $1+r$:

$$\frac{C-T}{1+r} < \frac{1}{r} \tag{1.1}$$

For $C < (1+r)/r$, as assumed above, this holds for any $T \geq 0$. This last condition states that the discounted cost minus tax should be smaller than the discounted (infinite) stream of future extra profits of the new technology (set to be equal to one in the Tirole set-up used here). However, the equation above is derived under the condition that it is not profitable for firm 2 to adopt — after all that is the case of competitive advantage even if $T = 0$. Thus the following condition should also be fulfilled. The foreign firm 2 will not adopt as long as the costs of adoption are higher than regaining the 'symmetric' adoption equilibrium:

$$\frac{(1+r)(\Pi-1)}{r} \geq \frac{(1+r)\Pi}{r} - C$$

Cancellation of the Π term yields:

$$\frac{C}{1+r} \geq \frac{1}{r} \tag{1.2}$$

This contradicts the basic assumption that

$$\frac{1+r}{r} > C > 1.$$

Hence, firm 2 will follow immediately.

Proposition 1.2 *If only one country imposes an environmental tax, non-adoption is no longer an equilibrium and both firms adopt the new technology immediately. The home firm — in contrast to the Porter Hypothesis — has no advantage.*

We will show below in a profit maximizing setting that this result is modified if adoption is delayed because later adoption is cheaper.

2 An Application to the Hotelling model

The basic idea of the previous section can easily be carried out in the Hotelling framework. Following Hotelling (1929) we model households who buy one unit of a good, to be located on the unit interval [0,1] and firm 1, located at zero, has market share x and firm 2, located at point 1 of the interval, has market share $1-x$.[1] Household x has transport cost xt if he buys from firm 1 and $(1-x)t$ if he buys from firm 2. He is indifferent between buying from any of the two firms if he has equal utility net of costs from both. A firm that does innovate offers additional utility Δs. Indicating adoption by $\delta_{1,2}=1$ and non-adoption by $\delta_{1,2}=0$, equality of costs net of additional utility of household x from buying from any of the two firms can be written as follows:

$$p_1 - \delta_1 \Delta s + tx = \ p_2 - \delta_2 \Delta s + t(1-x)$$

Solving for x and $(1-x)$ respectively yields

$$x = [p_2 - p_1 + t - (\delta_2 - \delta_1)\Delta s]/2t \ \text{ and } \ 1 - x = [p_1 - p_2 + t + (\delta_2 - \delta_1)\Delta s]/2t$$

Taxes, τ, for non-adoption appear in a lump-sum fashion in the flow of profits of the firms where c denotes constant unit costs:

$$\Pi_i = (p_i - c)\frac{[p_j - p_i - (\delta_j - \delta_i)\Delta s + t]}{2t} - (1-\delta_i)\tau - \delta_i \frac{rC}{(1+r)}$$

Obviously, taxes do not appear in the first-order conditions of profit maximization of firms with respect to p_i, and therefore they do not appear in the reaction functions.

[1] We do not model the entry and location decision of the two firms. While this can also be done, it would be rather straightforward to rescale the outcome to reflect the unit interval of two established firms as we describe it here.

Table 4: Payoff matrix for Hotelling game: both firms taxed

Firm 1 ↓ \ Firm 2 ⟶	new	old
new	$t/2 - \frac{rC}{1+r}, t/2 - \frac{rC}{1+r}$	$\frac{(t+\Delta s/3)^2}{2t} - \frac{rC}{(1+r)}, \frac{(t-\Delta s/3)^2}{2t} - \tau$
old	$\frac{(t-\Delta s/3)^2}{2t} - \tau, \frac{(t+\Delta s/3)^2}{2t} - \frac{rC}{(1+r)}$	$\frac{t}{2} - \tau, \frac{t}{2} - \tau$

Calculation of reaction functions, equilibrium prices and profits (see Tirole 1988, Chapter 7) yields flows of profits as summarized in Table 4.

Comparing this pay-off matrix for flow profits with that of section 2 for discounted present values shows that the relation between flow and total taxes is $T = (1+r)\tau/r$. If $\tau > rC(1+r)$, it is clearly better for firms to adopt.

Proposition 2.1 *Firms adopt in the Hotelling framework if the environmental tax τ is sufficiently high, i.e. $\tau > rC(1+r)$, which yields a higher profit than non-adoption.*

2.1 Different forms of taxation

It may be interesting to note that other tax measures can easily fail to give an incentive for adoption. An exemption from a *specific consumption tax* in case of adoption ($\delta_1 = 1$), for example, leads to the following indifference condition for consumer x:

$$p_1 + (1-\delta_1)\tau - \delta_1\Delta s + tx = p_2 + (1-\delta_2)\tau - \delta_2\Delta s + t(1-x).$$

If both firms take the same decision, the tax term drops out in all following steps of the analysis and therefore will have no impact on the diagonal elements of the pay-off matrix. The tax exemption thus fails to provide an incentive for adoption. Next, consider an exemption from a *specific sales tax* paid by producers. The indifference condition is unaffected but profits are affected. The definition of profit becomes

$$\Pi_i = [p_i - (1-\delta_i)\tau - c][p_j - p_i - (\delta_j - \delta_i)\Delta s + t]$$

Table 5: Payoff matrix for Hotelling game: sales tax paid by producers

Firm 1 $\downarrow$ \ Firm 2 $\longrightarrow$	new	old
new	$t/2, t/2$	$\frac{(t+(\Delta s+\tau)/3)^2}{2t}, \frac{(t-(\Delta s+\tau)/3)^2}{2t}$
old	$\frac{(t-(\Delta s+\tau)/3)^2}{2t}, \frac{(t+(\Delta s+\tau)/3)^2}{2t}$	$t/2, t/2$

Successive calculation of first-order conditions, reaction functions, equilibrium prices and profits yields the flow of profits (gross of adoption costs) given in Table 5.

Proposition 2.2 *Exemptions from consumer taxes fail to provide an incentive for adoption. An exemption from specific sales taxes on producers has an impact only in the cases of asymmetric adoption behaviour. However, asymmetric adoption behaviour is not an equilibrium outcome.*

Next, consider an *ad valorem sales tax* exemption for firms. Profits are redefined to be

$\Pi_i = \{p_i[1 + (1 - \delta_i)\tau] - c\}[p_j - p_i - (\delta_j - \delta_i)\Delta s + t]$

First-order conditions can be written as

$[1 + (1 - \delta_i)\tau][p_j - p_i - (\delta_j - \delta_i)\Delta s + t] - \{p_i[1 + (1 - \delta_i)\tau] - c\} = 0$

Dividing this equation by $[1 + (1 - \delta_i)\tau]$ yields

$[p_j - p_i - (\delta_j - \delta_i)\Delta s + t] - \{p_i - c/[1 + (1 - \delta_i)\tau]\} = 0$

The production-cost term, c, did never appear in the pay-off matrix in all the cases discussed so far. Therefore the tax term will also vanish with it in this case if (non)-adoption behaviour is symmetric. This leads us to the following proposition:

Proposition 2.3 *Exemption from ad-valorem producer taxes do not affect the non-adoption equilibrium.*

All of these examples from the Hotelling model confirm a well known lesson: a tax policy must approach the problem directly. The difference with other tax and tariff lessons is that the incentive effect of x-best measures are in many other cases not zero as they are here (Bhagwati and Srinivasan 1983). Proposing indirect taxation measures for policy purposes then is tantamount to supporting the decision of the firms to avoid adoption or to using a different model. Therefore the definition of environmental policies which clarifies when a tax has to be paid is crucial. Attacking the problem directly will work in every model

2.2 International case of differing taxation

Let us now consider the above mentioned case in which the two firms are located equidistant from a national border.

Taxes, τ, for non-adoption appear again in a lump-sum fashion in the flow of profits of the firms, however they are now indexed to indicate that they belong to country 1 or 2 respectively[2]:

$\Pi_i = (p_i - c)\frac{[p_j - p_i - (\delta_j - \delta_i)\Delta s + t]}{2t} - (1-\delta_i)\tau_i - \delta_i rC/(1+r)$

The only difference with the first model now is that τ has a country index which applies also to the adoption tax. As taxes do not appear in the first-order conditions of profit maximization of firms with respect to p_i, and therefore they do not appear in the reaction functions. Calculation of reaction functions, equilibrium prices and profits (see Tirole 1988, Chapter 7) yields flows of profits as summarized in Table 6.

If $\tau(1) < rC/(1+r < \tau(2)$. Then , starting in a non-adoption situation for both firms, firm 2 now has an incentive to adopt, whereas firm 1 does not. In this situation firm 1 would loose also some market share. Therefore firm 1 will compare profits under the assumption that firm 2 adopts. The comparison yields that firm 1 will adopt if

$$\frac{t}{2} - \frac{rC}{1+r} > \frac{(t - \Delta s/3)^2}{2t} - \tau_1$$

[2]Negative τ can be interpreted as a subsidy. Therefore the same calculations and argumentation could be applied to subsidies.

or

$$\frac{t}{2} - \frac{(t - \Delta s/3)^2}{2t} > \frac{rC}{1+r} - \tau_1 > 0$$

If differences in gross profits are larger than differences in adoption cost, firm 1 will follow and the Porter hypothesis does not hold, because the firm with the more environmentally friendly government has no advantage. If the condition does not hold, firm 1 does not adopt and firm 2 has an advantage because of an increase in gross profits under no additional conditions:

$$\frac{(t + \Delta s/3)^2}{2t} - \frac{rC}{1+r} > \frac{t}{2} - \tau_2$$

holds if

$$\frac{(t + \Delta s/3)^2}{2t} - \frac{t}{2} > \frac{rC}{1+r} - \tau_2$$

This holds as

$$\frac{(t + \Delta s/3)^2}{2t} - \frac{t}{2} = \frac{(\Delta s/3)^2 + 2t\Delta s/3}{2t} > 0 > \frac{rC}{1+r} - \tau_2$$

Proposition 2.4 *If two countries have different taxes on non-adoption, such that they are higher than adoption costs in one of them and lower in the other, the Porter hypothesis holds if the avoidance of loss in market share and profits through second adoption is insufficient to outweigh the adoption costs net of the taxes avoided.*

However, this result hinges on several assumptions. First of all, we have assumed that consumers themselves do not have any preferences for the goods that are produced using the cleaner technology. In that respect we have eliminated one of the main aspects in which the Hotelling model allows to diminish the (price) competition, namely the differentiation of goods.[3] However, the transport costs have the same effect.

[3] Eriksson (2004) has shown this to yield some results for the clean technology. He does not relate his

Table 6: Payoff matrix for international Hotelling game: both firms taxed

Firm 1 $\downarrow$ \ Firm 2 $\longrightarrow$	new	old
new	$t/2 - \frac{rC}{1+r}, t/2 - \frac{rC}{1+r}$	$\frac{(t+\Delta s/3)^2}{2t} - \frac{rC}{(1+r)}, \frac{(t-\Delta s/3)^2}{2t} - \tau_2$
old	$\frac{(t-\Delta s/3)^2}{2t} - \tau_1, \frac{(t+\Delta s/3)^2}{2t} - \frac{rC}{(1+r)}$	$\frac{t}{2} - \tau_1, \frac{t}{2} - \tau_2$

On the other hand we have not focussed on location competition *after* the environmental regulation takes place. Quite often polluting firms locate 'across the border' if markets in the border region are to be served. However, for existing firms the relocation of production brings significant adjustment costs which would warrant to question immediate reactions of already existing firms.

3 Conclusion

Given the prominent role of innovation offsets in the Porter Hypothesis we did prefer to model it using a framework of technology adoption by Fudenberg and Tirole in which non-adoption is an equilibrium outcome although firms are profit maximizing.

In the static version of the model we did show that a non-adoption equilibrium can be destroyed by an environmental non-adoption tax. However, as the foreign firm follows there is, in contrast to the Porter Hypothesis, no advantage for the home firm .

This result also holds in the Hotelling version of the static model. Moreover, we show that taxes not directly targeting the non-adoption problem may fail to have an adoption incentive on the firms.

model to technology adoption or the Porter Hypothesis. His model has the crucial assumption that the population of consumers is heterogenous with respect to their preferences of clean production.

References

Ambec, S. and Barla, P.: 2002, A theoretical foundation of the Porter hypothesis, *Journal of International Economics* **75**(3), 355–560.

Ayres, R. U.: 1994, On economic disequilibrium and free lunch, *Environmental and Resource Economics* **4**(5), 435–454.

Barrett, S.: 1994, Strategic environmental policy and international trade, *Journal of Public Economics* **54**(3), 325–338.

Bhagwati, J. N. and Srinivasan, T. N.: 1983, *Lectures in International Trade*, MIT Press, Cambridge.

Eriksson, C.: 2004, Can green consumerism replace environmental regulation?, *Resource and energy economics* **26**(3), 281–293.

Feess, E. and Taistra, G.: 2001, Environmental regulations and managerial myopia, *Jahrbücher für Nationalökonomie und Statistik* **220**(1), 18–31.

Fudenberg, D. and Tirole, J.: 1987, Understanding rent dissipation: On the use of game theory in industrial organisation, *American Economic Review* **77**(2), 176–183.

Greaker, M.: 2003, Strategic environmental policy; eco-dumping or a green strategy?, *Journal of Environmental Economics and Management* **45**(3), 692–707.

Hotelling, H.: 1929, Stability in competition, *Economic Journal* **39**(153), 41–57.

Hübner, M.: 2001, Sleeping process patents and environmental innovation, *Jahrbücher für Nationalökonomie und Statistik* **222**(6), 706–718.

Jaffe, A. B. and Palmer, K.: 1997, Environmental regulation and innovation: A panel data study, *The Review of Economics and Statistics* **79**(4), 610–619.

Klein, M. and Rothfels, J.: 1999, Can environmental regulation of X-inefficient firms create a "double dividend"?, *Technical Report 103*, Institut für Wirtschaftsforschung Halle, Halle.

Mohr, R. D.: 2002, Technical change, external economies, and the Porter hypothesis, *Journal of Environmental Economics and Management* **43**(1), 158–168.

Palmer, K., Oates, W. E. and Portney, P. R.: 1995, Tightening environmental standards: The benefit-cost or the no-cost paradigm, *Journal of Economic Perspectives* **9**(4), 119–132.

Porter, M. E. and van der Linde, C.: 1995a, Toward a concept of the environment-competitiveness relationship, *Journal of Economic Perspectives* **9**(4), 97–118.

Schmutzler, A.: 2001, Environmental regulations and managerial myopia, *Environmental and Resource Economics* **18**, 87–100.

Simpson, D. R. and Bradford III, R. L.: 1996, Taxing variable cost: Environmental regulation as industrial policy, *Journal of Environmental Economics and Management* **30**(3), 282–300.

Tirole, J.: 1988, *The Theory of Industrial Organisation*, MIT Press.

Ulph, A.: 1996a, Environmental policy and international trade when governments and producers act strategically, *Journal of Environmental Economics and Management* **30**(3), 265–281.

Ulph, A.: 1996b, Strategic environmental policy and international trade – the role of market conduct, *in* C. Carraro, Y. Katsoulacos and A. Xepapadeas (eds), *Environmental Policy and Market Structure*, Kluwer Academic Publishers, Dordrecht, pp. 99–127.

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